All other intermolecular context are of the normal van der Waals type. The molecular geometry is normal, with the plane of one of the carboxyl groups in the molecule roughly normal to the plane of the central ring atoms, the methoxy groups themselves being twisted out of this plane by about 10°.

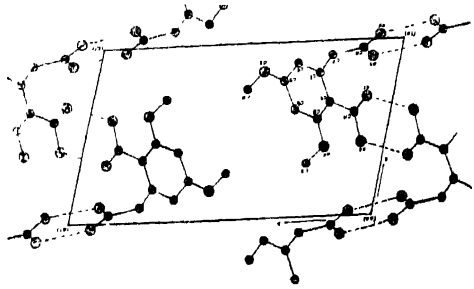

Fig. 1

The structure is being further refined to locate the hydrogen atoms to see if the hydrogen bonds are of the bent type.

Reference

Germain G., Main P. & Woolfson M. M. 1971 *Acta Cryst.* **A27**, 368.

Indian J. Phys. **50**, 1052-1056 (1976)

Dielectric properties of fibrous amphibole

G Vijayasree, P. S. Mukherjee and S. Bhattacherjee

Physics Department, Indian Institute of Technology, Kharagpur 721302

(*Received* 2 *August* 1976)

Amphiboles are chain silicate minerals and their fibrous forms are known to be asbestos which is widely used in industry as insulators. Dielectric constant of a mineral is considered to be one of the most significant properties in determining its electrical behaviour (Keller 1966). However, it can be seen from the data collected by Keller (1966) that practically no data exist on the dielectric properties of fibrous variety of amphiboles. In view of this fact an attempt has been made to study the frequency variation of dielectric constant and dielectric loss of a tremolite amphibole at temperatures around which transformations of the mineral normally occur (Deer *et al* 1963).

DTA records and X-ray powder photographs of the sample at these temperatures were also taken to identify the high temperature phases, if any, resulting from heating. Results of these measurements have been briefly reported in this short note.

A specimen of asbestos from Bihar identified as termolite amphibole by X-ray method by Mukherjee & Bhattacherjee (1976) was selected for the present investigation. Average chemical analysis data of the specimen have also been reported by the same authors. For observing the thermal behaviour DTA of the powdered sample was carried out by adopting the method described by Mitra & Bhattacherjee (1969) X-ray powder photographs of the finely powdered samples heated at 660°C, 760°C, 860°C and 960°C for four hours each were taken in a 114.6 mm Debye-Scherrer camera using nickel filtered CuK_α radiation.

The DTA curve shows a broad and slowly rising weak exothermic peak ranging from about 860°C to about 930°C immediately followed by a relatively sharper endothermic peak extending from 935°C–970°C. This indicates that the exothermic reaction is not well defined and may be attributed to the slow oxidation of the small amount of ferrous iron present in the sample without involving any apparent structural transformation as observed by Wittels (1952). The sharp endothermic peak is due to the loss of structural water accompanied by structural breakdown of tremolite into pyroxenes and silica according to equation (Deer *et al* 1963)

$$Ca_2Mg_5Si_8O_{22}(OH)_2 \longrightarrow 2CaSiO_3.5MgSiO_3 + SiO_2 + H_2O$$
(diops-clinoenstatite)

This is further confirmed by the X-ray powder photographs which show no apparent change in the pattern till 860°C. X-ray photographs for sample heated at 950°C show the absence of the strongest characteristic line of tremolite (8.33Å) and appearance of new lines at 3.165, 2.878, 2.490Å, characteristic of enstatite and that at 2·970 and 2·540Å of diopside respectveily (Encyclopedia of Minerals 1974).

Small circular pellets from the finely ground samples preheated at temperatures mentioned earlier were made at pressure of 4 tons/cm^2, for dielectric measurements as described by Bhattacharjee (1971) and for reasons discussed by Nigam (1976).

Dielectric constant and loss (tan δ) were measured from these samples in frequency range 10^5–10^7 c/s using a Marconi bridge (type TF 329G) and applying resonance curve method (Bhattacherjee 1971). Results have been shown graphically (Figs. 1, 2, 3, 4). Figs. 1, 2 reveal a marked variation of dielectric constants for sample at room temperature in the lower frequency range but the general pattern of frequency variation of dielectric constants remains almost the same at all other temperatures. The dielectric constant appear to differ considerably

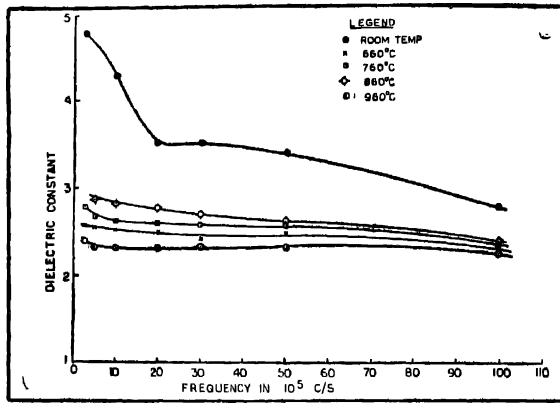

Fig. 1 Variation of dielectric constant with frequency corresponding to different tempera tures

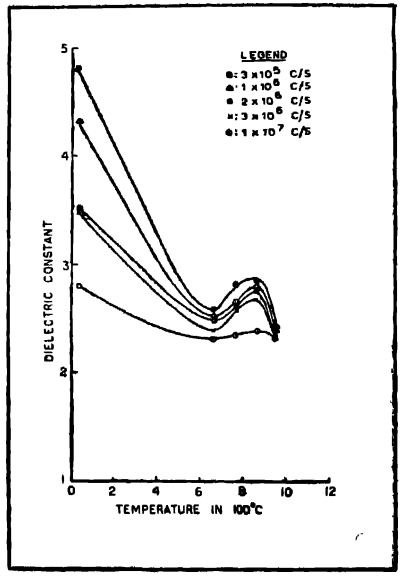

Fig. 2. Variation of dielectric constants with temperature corresponding to different froquency.

at low frequencies and at higher frequencies become practically frequency independent at all temperatures. This behaviour may be attributed to a dominant effect of space charge polarization at lower frequency range due to defect concentration (Rao & Smakula 1966) which is likely to increase with temperature. Contributions due to electronic and ionic polarisations that exist only at higher frequency is very small (Nigam 1976) The curves (2), (3), (4) of fig 1 corresponding to 660°C, 760°C and 860°C respectively reveal this temperature dependence of dielectric constant at all frequencies and are very similar to those reported by Keller (1966) for actinolite amphibole. However, the curves (1) and (5) corresponding to room temperature and 950°C respectively behave slightly differently. This difference in behaviour may be attributed to moisture content in (1) and to the formation of new phase as observed by *X*-ray photograph in (5) of figure 1.

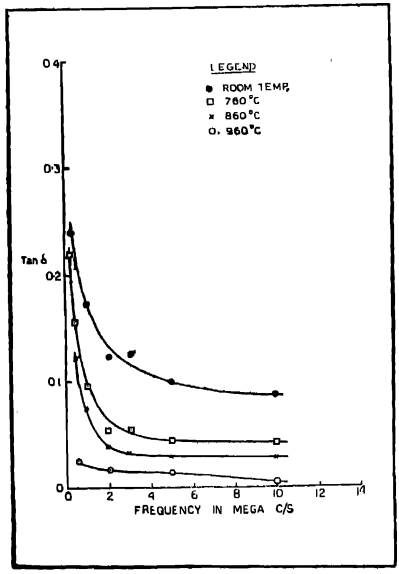

Fig. 3. Variation of dielectric loss (tan δ) with frequency corresponding to different temperatures.

Figure 2 shows a sharp drop of dielectric constant at about 660°C corresponding to all frequencies, the lower the minima the higher the frequency. Then all the curves show a slow rise giving a small hump around 850°C–900°C—finally fall sharply to a low value around 960°C. This behaviour is an indication of phase

transformation due to removal of structural water around this temperature as observed earlier in conformity with the X-ray and DTA results. This is further supported by the dielectric loss (tan δ) data (figures 3 and 4). The rapid fall of tan δ beyond about 850°C as the temperature increases is quite likely to be associated with a gradual structural transformation in the material under study. Thus it is seen that the results of dielectric measurements are quite in conformity with DTA and X-ray data Details of this work will be communicated soon.

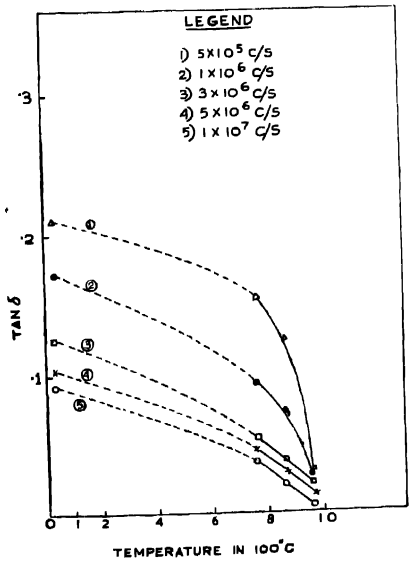

Fig. 4 Temperature variation of tan δ at different frequencies.

The authors express their sincere thanks to Prof. K. V Rao for his valuable suggestions and many helpful discussions and to Prof. G B. Mitra for his encouragement.

References

Bhattacharjee S. 1971 *Ind. J Pure & Appl. Phys* **9**, 1054.

Deer W. A., Howie R. A. & Zussman J. 1963 *Rock forming minerals*, Vol. 2, Chain Silicates, Longmans, 254.

Encyclopedia of Minerals 1974, Van Nostrand Reinhold Co . New York

Keller G. V. 1966 *Hand book of Physical Constants*, ed. Clark S. P. The Geophysical Society of America, 553.

Mitra G. B. & Bhattacherjee S. 1969 *Am. Min.* **54**, 1409.

Mukherjee P. S. & Bhattacherjee S. 1976 *Ind. J. Earth Sc.* Communicated.

Wittels M. 1952 *Am. Min.* **37**, 28.